Liver cirrhosis has a significant impact on the morphology and perfusion of the microvasculature of the liver

**Aim of this study:** to unravel the perfusion characteristics of the diseased cirrhotic microcirculation

### Data acquisition

1. **Vascular corrosion casting**
   - Injection of a polymer solution in both blood inlets: hepatic artery & portal vein
   - Maceration to dissolve liver tissue
   - Generate a replica of the vascular system

2. **High-resolution micro-CT imaging and scanning electron microscopy (SEM)**
   - Smaller samples are dissected from the cast to obtain a resolution of 1.7 - 1.9 μm
   - SEM clearly demonstrates the impact of cirrhosis on the microcirculation (e.g. shunt vessels, affected vessel walls, etc.)

### Image processing and CFD setup

1. **Anatomically correct 3D reconstructions of the microcirculation**
   - Cubic samples are virtually dissected to define the fluid domain for the CFD simulations of blood flow in three orthogonal directions (radial (r), circumferential (theta) and longitudinal (z))
   - To study the more subtle sinusoidal changes due to cirrhosis
   - To examine the influence of shunt vessels

2. **CFD model**

3. **Calculation of the permeabilities and porosity in order to characterise the perfusion properties of the microcirculation**
   - Permeability by applying Darcy's law (flow through porous medium)
     \[ \nabla P = \frac{-\mu \nabla \cdot \mathbf{u}}{k_f} \]
   - Porosity
     \[ \varepsilon = \frac{V_{\text{fluid}}}{V_{\text{sample}}} \]

### Results of the numerical CFD simulations

1. **Hemodynamic analysis**
   - Morphological differences: dilated sinusoids (sample 1) and shunt vessels (sample 2) are absent in normal liver tissue
   - The pressure drop over the cirrhotic samples is lower along all three directions compared to normal sample. This is probably due to more diluted sinusoidal lumens, which decrease the resistance to flow
   - Preferential pathways are formed in the geometry, transporting the vast majority of blood flow.

2. **Diagonalized permeability tensor (K) and porosity (ε) of the cirrhotic samples**
   - Both cirrhotic samples display an anisotropic permeability, with the highest permeability oriented parallel to the central vein (k_{xx}).
   - The permeability coefficients of the cirrhotic samples are an order of magnitude higher compared to normal liver tissue. This is most likely due to more dilated sinusoids and shunt vessels in the cirrhotic samples.
   - The porosity of the normal liver tissue and cirrhotic sample 1 are nearly identical. Cirrhotic sample 2, however, has a substantially higher porosity, which reduces the resistance to flow in all directions (shunts).

### Conclusion: Numerical modelling allowed quantifying the perfusion characteristics of the cirrhotic microcirculation

- The vascular samples suggest the cirrhotic microcirculation is characterized by an anisotropic permeability.
- The cirrhotic permeability coefficients are higher when compared to normal liver tissue, implying a decreased resistance. This probably indicates local compensation mechanisms (dilated sinusoids and shunt vessels) to counteract the increased resistance of the liver as a whole (due to regenerative nodules and dynamic contraction mechanisms).
- Future research will focus on the development of multiscale models to couple the macro- and microcirculation. Furthermore, a well-established cirrhotic rat model will be studied to model the degenerative adaptation of the cirrhotic (micro)circulation.